

Comment on “Turnaround in Cyclic Cosmology”

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Recently, it has been claimed that the entropy problem can be resolved in a peculiar cyclic cosmology [1]. The authors of the Letter proposed a spawn mechanism for helping reconcile the infinitely cyclic cosmology with the second law of thermodynamics. Here, we shall show that the spawn mechanism is unlikely to be correct.

The Letter employed the phantom bounce model [2] as a specific cyclic universe model. The Friedmann equation of this model is given by

$$H^2 = \frac{8\pi G}{3}\rho \left(1 - \frac{\rho}{\rho_c}\right), \quad (1)$$

where $H = \dot{a}/a$ is the Hubble parameter, and ρ_c is the critical energy density set by quantum gravity, which is the maximal density of the universe. Such a modified Friedmann equation with a phantom energy component leads to a cyclic universe scenario in which the universe oscillates through a series of expansions and contractions. In the usual universe, the phantom dark energy leads to a “big rip” singularity; however, in this peculiar cyclic universe, the big-rip singularity can be avoided because when ρ reaches ρ_c the universe will turn around due to Eq. (1).

The authors of the Letter [1] argued that at the turnaround point, our universe will be fragmented into a large number of disconnected causal patches, each of which independently contracts as a separate universe. The entropy of each causal patch is essentially zero, i.e., $S = \mathcal{O}(1)$ compared to the earlier $S > 10^{88}$. This dramatic decrease in entropy is called deflation by the authors, which is claimed to provide a solution to the entropy problem.

However, we shall show that this spawn mechanism (deflationary hypothesis) is not realistic, i.e., our universe can not be fragmented into independently causal patches at the turnaround. According to Eq. (1), though the phantom energy density ρ always increases with the expansion of the universe [3], the Hubble parameter H does not monotonously increase, see Fig. 1. From Fig. 1, it is clear that the Hubble parameter H increases within the range $0 < \rho < \rho_c/2$ and decreases within the range $\rho_c/2 < \rho < \rho_c$; H gets its maximum at $\rho = \rho_c/2$ (we call the corresponding time t_{\max}). Turnaround occurs at a time t_T , when $H(t_T) = 0$ (corresponding to $\rho = \rho_c$). Therefore, obviously, at the turnaround t_T , the Hubble length becomes infinity, $H^{-1} \rightarrow \infty$ (see also [4]). It is clear that though phantom energy makes bound systems become unbound and the constituents causally

disconnect around t_{\max} , the many causally disconnected patches reconnects together at the turnaround t_T , if we believe that the Hubble length plays an important role in establishing the range of causal interaction or the size of a causal region. So, we conclude that the universe would not be fragmented into many disconnected causal patches at the turnaround.

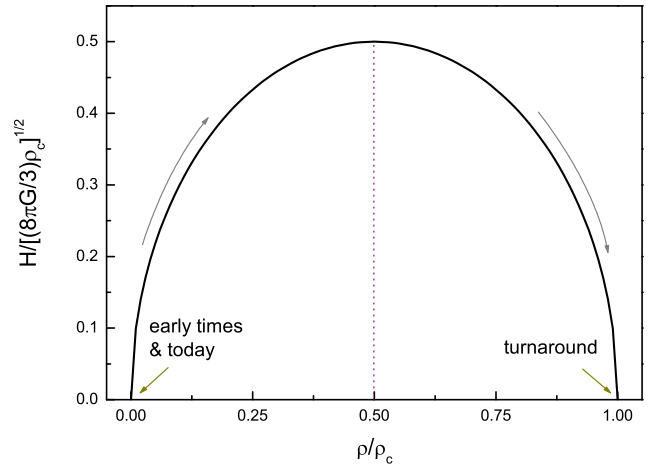


FIG. 1: Sketch map of the expanding phase of phantom dominated universe in the cyclic cosmology.

It should be stressed that understanding the physics very near turnaround is necessary to demonstrate the validity of the fragmentation hypothesis. According to the analysis in this Comment, the idea of Ref. [1] is albeit attractive but unlikely to be correct. The entropy problem still exists in this peculiar cyclic cosmology.

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- [1] L. Baum and P. H. Frampton, Phys. Rev. Lett. **98**, 071301 (2007) [hep-th/0610213].
 - [2] M. G. Brown, K. Freese and W. H. Kinney, astro-ph/0405353.
 - [3] We only consider the phantom dominated era in the expanding branch, so the universe is in the high energy regime, $\rho \gg \rho_{\text{today}}$; we often say $\rho_{\text{today}} \sim 0$ (hence $H_{\text{today}} \sim 0$).
 - [4] X. Zhang, arXiv:0708.1408 [gr-qc].